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ABSTRACT:

PROBLEM TO BE SOLVED: To perform clock reproduction without using an electric circuit, which requires a high-speed operation, by utilizing the merit of a DPSK-DD(differential phase shift keying-direct detection) system.

SOLUTION: A light receiver is provided with a Mach-Zehnder interferometer 13 for branching the phase modulated light into two, setting a delay bit length D for one of signal light to the range of 0<D<2, having both signal light interfered each other and converting them to intensity modulated light, a balance type light receiver 14 for receiving the two output of the Mach-Zehnder interferometer 13 and converting them to electric signals, a narrow-band filter 16 for extracting clock frequency components from the electric signals and a limiter amplifier 17 for fixing the amplitude of clock signals outputted from the narrow- band filter 16.

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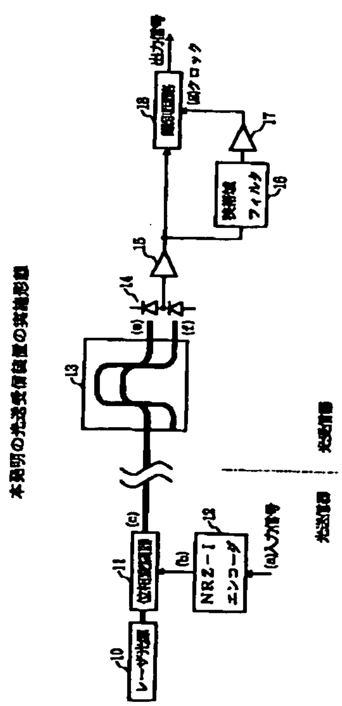
(54)【発明の名称】　光送受信装置

(57)【要約】

【課題】　ＤＰＳＫ－ＤＤ方式の長所を活かし、高速動作が要求される電気回路を用いずにクロック再生を行う。

【解決手段】　光受信器は、位相変調光を２分岐し、一方の信号光に対する遅延ビット長Ｄを０＜Ｄ＜２の範囲で設定し、両信号光を干渉させて強度変調光に変換するマッハツェンダ干渉計と、マッハツェンダ干渉計の２出力を受光して電気信号に変換するバランス型受光器と、電気信号からクロック周波数成分を抽出する狭帯域フィルタと、狭帯域フィルタから出力されるクロック信号の振幅を一定にするリミッタアンプとを備える。



【特許請求の範囲】

【請求項1】 無変調光をNRZ－I符号の信号で位相変調し、位相変調光を出力する光送信器と、

前記位相変調光を受光し、クロック信号を再生して信号識別を行う光受信器とを備えた光送受信装置において、

前記光受信器は、

前記位相変調光を2分岐し、一方の信号光に対する遅延ビット長Dを0＜D＜2の範囲で設定し、両信号光を干渉させて強度変調光に変換するマッハツェンダ干渉計と、

前記マッハツェンダ干渉計の2出力を受光して電気信号に変換するバランス型受光器と、

前記電気信号からクロック周波数成分を抽出する狭帯域フィルタと、

前記狭帯域フィルタから出力されるクロック信号の振幅を一定にするリミッタアンプとを備えたことを特徴とする光送受信装置。

【請求項2】 請求項1に記載の光送受信装置において、

マッハツェンダ干渉計は、一方の信号光に対する遅延ビット長Dを1／2≦D≦1の範囲で設定することを特徴とする光送受信装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、コヒーレント光通信に用いられる光送受信装置において、差動位相変調－直接検波（DPSK－DD）方式を利用してクロック再生を行う光送受信装置に関する。

【0002】

【従来の技術】DPSK－DD方式は、入力信号が「1」の場合には直前の符号を反転した符号、「0」の場合には直前の符号と等しい符号となるNRZ－I符号の信号を生成し、このNRZ－I符号の信号で無変調光を位相変調して送信し、受信側ではこの位相変調光をバランス型受光器で直接検波する方式である。DPSK－DD方式は、強度変調－直接検波（IM－DD）方式に比べて受光感度がよいので、長距離光伝送に適した光通信方式として実用化が期待されている。

【0003】また、DPSK－DD方式はバランス型受光器を用いた差動受信方式であり、信号を識別する閾値を入力信号光強度に関わらず常に信号振幅の中央に保てるので、信号光のレベル変動に強い特徴がある。したがって、近年では光ATMスイッチ等のように、光パケット信号を光の領域で交換するシステムに適用する光送受信方式として実用化が期待されている。

【0004】一方、長距離光伝送や光ATMスイッチなどの光通信システムでは、信号光からのクロック再生が重要な課題になっており、クロック再生に適した通信方式や符号化方式が多数提案されている。

【0005】ここで、最も一般的な例として、IM－DD方式でNRZ符号を用いた場合のクロック再生技術について説明する。図5，6は、従来の光送受信装置の構成例を示す。

【0006】図5において、光送信器は、レーザ光源50および強度変調器51により構成される。光送信器に対向する光受信器は、フォトダイオード52、線形増幅器53、1／2ビット遅延器54、排他的論理和（EXOR）回路55、狭帯域フィルタ56、リミッタアンプ57、識別回路58により構成される。

【0007】レーザ光源50から出力された光は、強度変調器51でNRZ符号の入力信号によって強度変調される。この信号光は、対向する光受信器のフォトダイオード52に受光され、電気信号に変換される。この電気信号は線形増幅器53で増幅され、さらに2分岐して一方が識別回路58に入力され、他方がクロック再生に用いられる。クロック再生用に分岐された電気信号は、さらに2分岐して一方がEXOR回路55に入力され、他方が1／2ビット遅延器54で1／2ビットの遅延を受けてEXOR回路55に入力される。この結果、EXOR回路55からは、クロックと同じ帯域をもつ信号が出力され、狭帯域フィルタ56によってクロック周波数成分が抽出される。抽出されたクロック信号は、リミッタアンプ57で強度が一定になって識別回路58に与えられる。

【0008】図6において、光送信器は、レーザ光源60および強度変調器61により構成される。光送信器に対向する光受信器は、フォトダイオード62、線形増幅器63、逓倍回路64、狭帯域フィルタ65、リミッタアンプ66、識別回路67により構成される。

【0009】レーザ光源60から出力された光は、強度変調器61でNRZ符号の入力信号によって強度変調される。この信号光は、対向する光受信器のフォトダイオード62に受光され、電気信号に変換される。この電気信号は線形増幅器63で増幅され、さらに2分岐して一方が識別回路67に入力され、他方がクロック再生に用いられる。逓倍回路64は、クロック再生用に分岐された電気信号を入力し、微分・全波整流によってクロックと同じ帯域をもつ信号を出力し、狭帯域フィルタ65によってクロック周波数成分が抽出される。抽出されたクロック信号は、リミッタアンプ66で強度が一定になって識別回路67に与えられる。

【0010】

【発明が解決しようとする課題】例えば、10Gbit/s の通信では、光受信器内で識別再生を行う際に必要となるクロック周波数は10GHzである。しかし、10Gbit/s のNRZ符号列は、周波数帯域が0～5GHz程度の範囲に分布しているためにクロック周波数成分を含まない。したがって、信号に同期したクロックを抽出するためには、受信したNRZ符号列からクロック周波数成分を作り出す電気回路が必要となる。

【0011】図5に示す従来構成では、クロック周波数成分を作り出すためにＥＸＯＲ回路５５が用いられ、図6に示す従来構成では逓倍回路６４が用いられている。これらの電気回路は、信号速度の2倍の速度で駆動しなければならないので、数十Gbit/s クラスの高速光通信に適用する際には回路の作成が困難になる。

【0012】本発明は、ＤＰＳＫ－ＤＤ方式の長所を活かし、高速動作が要求される電気回路を用いずにクロック再生を行うことができる光送受信装置を提供することを目的とする。

【0013】

【課題を解決するための手段】本発明は、無変調光をＮＲＺ－Ｉ符号の信号で位相変調し、位相変調光を出力する光送信器と、位相変調光を受光し、クロック信号を再生して信号識別を行う光受信器とを備えた光送受信装置において、光受信器は、位相変調光を２分岐し、一方の信号光に対する遅延ビット長Ｄを０＜Ｄ＜２の範囲で設定し、両信号光を干渉させて強度変調光に変換するマッハツェンダ干渉計と、マッハツェンダ干渉計の２出力を受光して電気信号に変換するバランス型受光器と、電気信号からクロック周波数成分を抽出する狭帯域フィルタと、狭帯域フィルタから出力されるクロック信号の振幅を一定にするリミッタアンプとを備えて構成する。

【0014】また、マッハツェンダ干渉計は、一方の信号光に対する遅延ビット長Ｄを１／２≦Ｄ≦１の範囲で設定することが好ましい。

【0015】

【発明の実施の形態】図１は、本発明の光送受信装置の実施形態を示す。図2は、図１の各点における符号列を示す。

【0016】図において、光送信器は、レーザ光源１０、位相変調器１１およびＮＲＺ－Ｉエンコーダ１２により構成される。光送信器に対向する光受信器は、マッハツェンダ（ＭＺ）干渉計１３、バランス型受光器１４、線形増幅器１５、狭帯域フィルタ１６、リミッタアンプ１７、識別回路１８により構成される。

【0017】ＮＲＺ－Ｉエンコーダ１２は、ＮＲＺ符号の入力信号（図２(a) ）を入力し、信号「１」の場合には直前の符号を反転した符号、信号「０」の場合には直前の符号と等しい符号となるＮＲＺ－Ｉ符号の信号（図２(b) ）に変換して出力する。位相変調器１１は、レーザ光源１０から出力された無変調光をＮＲＺ－Ｉ符号の信号によって位相変調し、０とπの２値の位相変調信号（図２(c) ）を出力する。この位相変調信号は、対向する光受信器のＭＺ干渉計１３に入力される。

【0018】ＭＺ干渉計１３は、一方の３ｄＢカプラで入力信号光を２本のアーム導波路に２分岐し、その一方の信号光に対して遅延ビット長Ｄを０＜Ｄ＜２の範囲で遅延させ、他方の３ｄＢカプラで２分岐された信号光を合波して干渉させる構成であり、その位相差に応じて位相変調光を強度変調光に変換する。図2は、遅延ビット長Ｄが0.8 の場合であり、(d) は干渉した２波の位相差を示し、(e),(f) は干渉後にＭＺ干渉計１３の２ポートから出力される強度変調光を示す。

【0019】ＭＺ干渉計１３の２つのポートから出力される強度変調光は、バランス型受光器１４に受光されて電気信号に変換される。この電気信号は線形増幅器１５で増幅され、さらに２分岐して一方が識別回路１８に入力され、他方がクロック再生に用いられる。狭帯域フィルタ１６は、クロック再生用に分岐された電気信号を入力し、クロック周波数成分を抽出する。抽出されたクロックは、リミッタアンプ１７で強度が一定に制御されて識別回路１８に与えられる。図２(g) は、再生されたクロックを示す。

【0020】なお、ＭＺ干渉計１３における遅延ビット長Ｄは、１／２≦Ｄ≦１の範囲の設定が好ましい。以下、その理由について詳細に説明する。データ受信の際には、信号がクロック周波数成分を含み、かつ検波信号のパルス幅が広いほど正確な受信ができる。ここで、遅延ビット長Ｄとクロック周波数成分およびパルス幅との関係を図３に模式的に示す。

【0021】信号のパルス幅は、Ｄ＝１のときに最大の広がりをもち、Ｄ＝１より大きくても小さくてもパルス幅が狭くなる。いま、注目しているビットをｎ番目のビットとすると、Ｄ＝１では隣接するビット同士、すなわちｎ番目のビットとｎ＋１番目のビットが完全に干渉し、ＮＲＺ－Ｉ符号の信号を効率よく検波することができる。また、Ｄが１より小さくなると、隣接するｎ番目とｎ＋１番目のビット間だけでなく、ｎ番目のビット同士の干渉が発生する。この結果、パルス幅は狭くなり、信号波形はＲＺ符号に近づいていく。Ｄ＝０の極限ではパルス幅は０になり、スペースの連続になる。一方、Ｄが１より大きくなると、隣接するｎ番目とｎ＋１番目のビット間の干渉に加えて、ｎ番目とｎ＋２番目のビット間の干渉が発生する。この部分は、受信器によって再生されるデータには関係なく単にパルス幅を狭くすることから、１＜Ｄ＜２の領域は原理的には受信可能であるが実用的ではない。Ｄ＝２の極限では隣接するｎ番目とｎ＋１番目のビット間の干渉が完全になくなり、ｎ番目とｎ＋２番目のビット間の干渉のみとなり、受信不能になる。

【0022】以上の説明では、ＮＲＺ－Ｉ符号の信号の検波に関しては、Ｄ＝１であることが最適と言える。しかし、検波信号の識別にはクロックが必要であり、そのクロックを検波信号から抽出再生する必要がある。そのためには、検波信号がクロック周波数成分を含んでいる必要がある。従来構成ではＥＸＯＲ回路や逓倍回路を用い、電気領域でクロック周波数成分を抽出していたが、本実施形態の構成ではＭＺ干渉計１３における遅延ビット長Ｄを調整することにより、クロック周波数成分を多

く含む信号を生成し、簡単な構成でクロック再生を可能にする。

【００２３】クロック周波数成分を最も多く含むのは、図3に示すようにD＝１／２の付近であり、ＭＺ干渉計１３の出力信号波形がＲＺ信号とほぼ等価な波形になる。Dが１／２から0に向かうにつれて、また1に近づくにつれてクロック周波数成分は小さくなり、受信器の性能は低下する。なお、１＜D＜２の領域でも所定のクロック周波数成分を含んでいる。

【００２４】このように、遅延ビット長Dが１／２付近では、ＭＺ干渉計１３からの出力信号がクロック周波数成分を多く含むことから、クロックの再生効率が最もよい。また、遅延ビット長Dが１／２から１に近づくにつれてビットの幅が広がり、識別の際にビット誤りを起こしにくくなる。その反面、クロック周波数成分が減少し、クロックの再生効率が遅延ビット長１／２のときに比べて劣化する。したがって、ＭＺ干渉計１３における遅延ビット長Dは、１／２≦D≦１の範囲の設定が好ましいと言える。

【００２５】なお、ＭＺ干渉計１３の一方のアーム導波路に例えばヒータを蒸着し、熱光学効果を利用して光学長を可変させ、遅延ビット長Dを可変させる構成としてもよい。

【００２６】図4は、本発明の光送受信装置をコヒーレント光通信システムに適用した実施例構成を示す。図において、光送信器は、レーザ光源４０、位相変調器４１およびＮＲＺ－Ｉエンコーダ４２により構成される。光伝送路および光スイッチング網を介して光送信器に対向する光受信器は、遅延ビット長が１／２に設定されたＭＺ干渉計４３、バランス型受光器４４、線形増幅器４５、ローパスフィルタ（ＬＰＦ）４６、狭帯域フィルタとしてＳＡＷフィルタ４７、リミッタアンプ４８、識別回路としてD－フリップフロップ（Ｄ－ＦＦ）４９により構成される。

【００２７】位相変調器４１は、例えば$LiNbO_3$によって形成される光導波路からなり、ＮＲＺ－Ｉエンコーダ４２から出力されるＮＲＺ－Ｉ符号の信号によって駆動され、レーザ光源４０から出力されるレーザ光をＮＲＺ－Ｉ符号に位相変調する。この位相変調光は、光伝送路および光スイッチング網を介してＭＺ干渉計４３に入力される。

【００２８】ＭＺ干渉計４３は、入力信号光を２分岐し、その一方の信号光を１／２ビット遅延し、両信号光を干渉させて強度変調光を生成する。なお、このときの強度変調光はＲＺ符号となり、マークとスペースでＭＺ干渉計４３の2つのポートにそれぞれ出力され、バランス型受光器４４で電気信号に変換される。この電気信号は線形増幅器４５で増幅され、さらに２分岐し、一方がＬＰＦ４６を介して高周波成分がカットされてパルス幅が広げられ、Ｄ－ＦＦ４９に入力される。他方の電気信号は、ＳＡＷフィルタ４７に入力されてクロック周波数成分が抽出され、リミッタアンプ４８で強度が一定に制御されてＤ－ＦＦ４９のクロック端子に与えられる。

【００２９】

【発明の効果】以上説明したように、本発明の光送受信装置は、ＭＺ干渉計の遅延ビット長Dを調整することにより、光信号からクロック周波数成分を作りだすことができる。従来は、ＥＸＯＲ回路や逓倍回路を用い、電気領域でクロック周波数成分を抽出していたので、信号速度の２倍の高速動作を必要としていたが、本発明の光送受信装置では高速動作が要求される電気回路が不要となる。すなわち、簡単な構成で数十Gbit/s クラスの高速光通信のクロック再生に適用することができる。

【図面の簡単な説明】

【図１】本発明の光送受信装置の実施形態を示すブロック図。

【図２】図１の各点の信号波形を示す図。

【図３】遅延ビット長Dとクロック周波数成分およびパルス幅の関係を模式的に示す図。

【図４】本発明の光送受信装置をコヒーレント光通信システムに適用した実施例構成を示すブロック図。

【図５】従来の光送受信装置の構成例を示すブロック図。

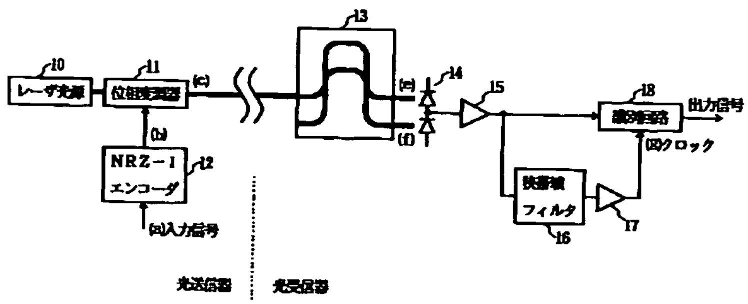
【図６】従来の光送受信装置の構成例を示すブロック図。

【符号の説明】

１０，４０　レーザ光源
１１，４１　位相変調器
１２，４２　ＮＲＺ－Ｉエンコーダ
１３，４３　マッハツェンダ（ＭＺ）干渉計
１４，４４　バランス型受光器
１５，４５　線形増幅器
１６　狭帯域フィルタ
１７，４８　リミッタアンプ
１８　識別回路
４６　ローパスフィルタ（ＬＰＦ）
４７　ＳＡＷフィルタ
４９　Ｄ－フリップフロップ（Ｄ－ＦＦ）
５０，６０　レーザ光源
５１，６１　強度変調器
５２，６２　フォトダイオード
５３，６３　線形増幅器
５４　１／２ビット遅延器
５５　排他的論理和（ＥＸＯＲ）回路
５６，６５　狭帯域フィルタ
５７，６６　リミッタアンプ
５８，６７　識別回路
６４　逓倍回路

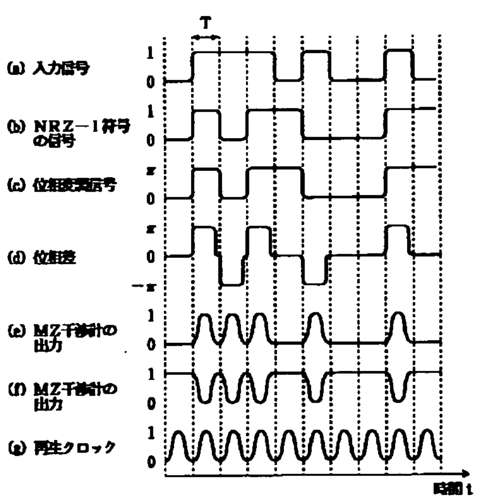
【図1】

本発明の光送受信装置の実施形態



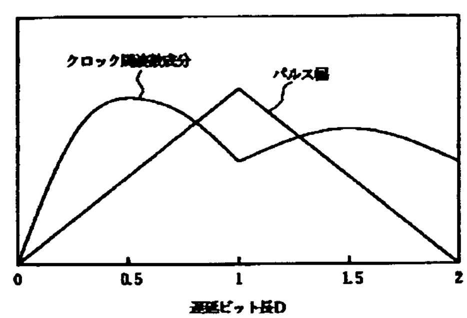
【図2】

図1の各点の信号波形



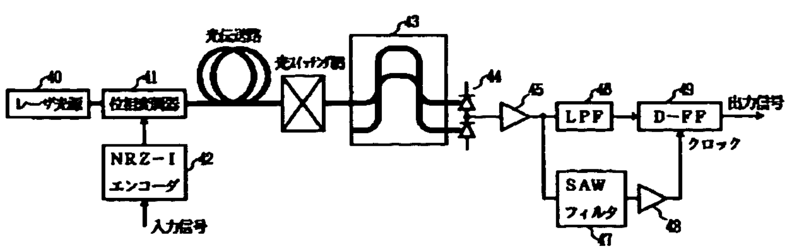
【図3】

遅延ビット長Dとクロック周波数成分およびパルス幅との関係



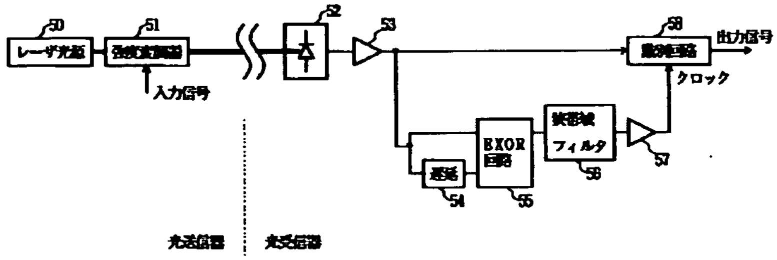
【図4】

本発明の光送受信装置をコヒーレント光通信システムに適用した実施例構成



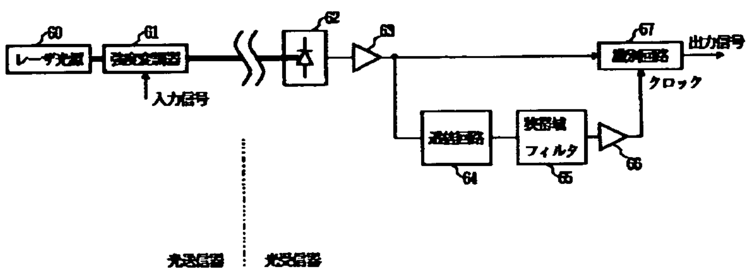
【図5】

従来の光送受信装置の構成例



【図6】

従来の光送受信装置の構成例



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H04B　10/06

PAT-NO: JP02000059300A

DOCUMENT-IDENTIFIER: JP 2000059300 A

TITLE: **LIGHT TRANSMITTER-RECEIVER**

PUBN-DATE: **February 25, 2000**

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APPL-NO: JP10222865

APPL-DATE: August 6, 1998

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ABSTRACT:

PROBLEM TO BE SOLVED: To perform clock reproduction without using an electric circuit, which requires a high-speed operation, by utilizing the merit of a DPSK-DD(differential phase shift keying-direct detection) system.

SOLUTION: A light receiver is provided with a Mach-Zehnder interferometer 13 for branching the phase modulated light into two, setting a delay bit length D for one of signal light to the range of 0<D<2, having both signal light interfered each other and converting them to intensity modulated light, a balance type light receiver 14 for receiving the two output of the Mach-Zehnder interferometer 13 and converting them to electric signals, a narrow-band filter 16 for extracting clock frequency components from the electric signals and a limiter amplifier 17 for fixing the amplitude of clock signals outputted from the narrow- band filter 16.

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CLAIMS (JP-2000-059300A)

[Claim(s)]

[Claim 1] An optical transmitter-receiver equipped with an optical transmitter which carries out the phase modulation of the light characterized by providing the following non-become irregular by signal of an NRZI code, and outputs phase modulation light, and an optical receiver which receives said phase modulation light, reproduces a clock signal, and performs a signal decision Said optical receiver is a Mach-Zehnder interferometer which dichotomize said phase modulation light, set up delay bit length D to one signal light in 0< D<2, and both signal light is made to interfere, and is changed into on-the-strength strange dimming. A balance mold electric eye which receives two outputs of said Mach-Zehnder interferometer, and is changed into an electrical signal A narrow band filter which extracts a clock frequency component from said electrical signal Limiter amplifier which makes regularity amplitude of a clock signal outputted from said narrow band filter

[Claim 2] It is the optical transmitter-receiver characterized by a Mach-Zehnder interferometer setting up delay bit length D to one signal light in 1 / 2<=D<=1 in an optical transmitter-receiver according to claim 1.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] When an input signal is "1", the sign which reversed the last sign, and the signal of an NRZI code which turns into the last sign and an equal sign in the case of "0" are generated, and by the signal of this NRZI code, the phase modulation of the light non-become irregular is carried out, it transmits, and a DPSK-DD method is a method which detects this phase modulation light directly by the balance mold electric eye in a receiving side. Since a DPSK-DD method has good light-receiving sensitivity compared with an intensity modulation-direct detection (IM-DD) method, utilization is expected as an optical communication type suitable for long-distance optical transmission.

[0003] Moreover, a DPSK-DD method is a differential receiving method which used the balance mold electric eye, and since it is not concerned with input signal light reinforcement but the threshold which identifies a signal can always be maintained in the center of signal amplitude, there is the feature strong against the level variation of signal light. Therefore, in recent years, utilization is expected as an optical transceiver method which applies an optical packet signal to the system exchanged in the field of light like an optical ATM switch.

[0004] On the other hand, in optical transmission systems, such as long-distance optical transmission and an optical ATM switch, the clock playback from signal light has been an important technical problem, and many communication modes suitable for clock playback and coding methods are proposed.

[0005] Here, the clock playback technology at the time of using an NRZ code by the IM-DD method is explained as most general example. Drawing 5 and 6 show the example of a configuration of the conventional optical transmitter-receiver.

[0006] An optical transmitter is constituted by a laser light source 50 and the modulator 51 on the strength in drawing 5 . The optical receiver which counters an optical transmitter is constituted by a photodiode 52, a linear amplifier 53, the 1/2-bit delay machine 54, the exclusive-OR (EXOR) circuit 55, a narrow band filter 56, the limiter amplifier 57, and the discrimination

decision circuit 58.

[0007] Intensity modulation of the light outputted from the laser light source 50 is carried out by the input signal of an NRZ code with the modulator 51 on the strength. Light is received by the photodiode 52 of the optical receiver which counters, and this signal light is changed into an electrical signal. This electrical signal is amplified with a linear amplifier 53, it dichotomizes further, one side is inputted into a discrimination decision circuit 58, and another side is used for clock playback. The electrical signal which branched to clock playback dichotomizes further, one side is inputted into the EXOR circuit 55, and another side is inputted into the EXOR circuit 55 in response to 1/2-bit delay with the 1/2-bit delay vessel 54. Consequently, a signal with the same band as a clock is outputted, and a clock frequency component is extracted from the EXOR circuit 55 by the narrow band filter 56. Reinforcement becomes fixed with the limiter amplifier 57, and the extracted clock signal is given to a discrimination decision circuit 58.

[0008] An optical transmitter is constituted by a laser light source 60 and the modulator 61 on the strength in drawing 6 . The optical receiver which counters an optical transmitter is constituted by a photodiode 62, a linear amplifier 63, the multiplying circuit 64, a narrow band filter 65, the limiter amplifier 66, and the discrimination decision circuit 67.

[0009] Intensity modulation of the light outputted from the laser light source 60 is carried out by the input signal of an NRZ code with the modulator 61 on the strength. Light is received by the photodiode 62 of the optical receiver which counters, and this signal light is changed into an electrical signal. This electrical signal is amplified with a linear amplifier 63, it dichotomizes further, one side is inputted into a discrimination decision circuit 67, and another side is used for clock playback. The multiplying circuit 64 inputs the electrical signal which branched to clock playback, and outputs the signal which has the same band as a clock by differential and full wave rectification, and a clock frequency component is extracted by the narrow band filter 65. Reinforcement becomes fixed with the limiter amplifier 66, and the extracted clock signal is given to a discrimination decision circuit 67.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] For example, 10 Gbit/s The clock frequency which is needed in a communication link in case discernment playback is performed within an optical receiver is 10GHz. However, 10 Gbit/s Since the NRZ code train is distributed over the range whose frequency band is about 0-5GHz, it does not contain a clock frequency component. Therefore, in order to extract the clock which synchronized with the signal, the electrical circuit which makes a clock frequency component is needed from the received NRZ code train.

[0011] Conventionally which is shown in drawing 5 , in order to make a clock frequency component with a configuration, the EXOR circuit 55 is used, and with the configuration, the multiplying circuit 64 is used conventionally which is shown in drawing 6 . Since it must drive by one twice the speed of a signal speed, these electrical circuits are dozens Gbit/s. Creation of a circuit becomes difficult in case it applies to the high-speed optical communication of a class.

[0012] This invention aims at offering the optical transmitter-receiver which can perform clock playback, without using the electrical circuit where high-speed operation is demanded taking advantage of the advantage of a DPSK-DD method.

[Translation done.]

MEANS

[Means for Solving the Problem] In an optical transmitter-receiver equipped with an optical transmitter which this invention carries out the phase modulation of the light non-become irregular by signal of an NRZI code, and outputs phase modulation light, and an optical receiver which receives phase modulation light, reproduces a clock signal, and performs a signal decision A Mach-Zehnder interferometer which an optical receiver dichotomizes phase modulation light, set up delay bit length D to one signal light in 0< D<2, and both signal light is made to interfere, and is changed into on-the-strength strange dimming, A balance mold electric eye which receives two outputs of a Mach-Zehnder interferometer and is changed into an electrical signal, a narrow band filter which extracts a clock frequency component from an electrical signal, and limiter amplifier which makes regularity amplitude of a clock signal outputted from a narrow band filter are had and constituted.

[0014] Moreover, as for a Mach-Zehnder interferometer, it is desirable to set up delay bit length D to one signal light in 1 / 2<=D<=1.

[0015]

[Embodiment of the Invention] Drawing 1 shows the operation gestalt of the optical transmitter-receiver of this invention. Drawing 2 shows the sign train in each point of drawing 1 .

[0016] An optical transmitter is constituted by a laser light source 10, a phase modulator 11, and the NRZ-I encoder 12 in drawing. The optical receiver which counters an optical transmitter is constituted by the Mach TSUENDA (MZ) interferometer 13, the balance mold electric eye 14, a linear amplifier 15, a narrow band filter 16, the limiter amplifier 17, and the discrimination decision circuit 18.

[0017] The NRZ-I encoder 12 inputs the input signal (drawing 2 (a)) of an NRZ code, and, in the case of a signal "1", in the case of the sign and signal "0" which reversed the last sign, changes and outputs it to the signal (drawing 2 (b)) of an NRZI code used as the last sign and an equal sign. A phase modulator 11 carries out the phase modulation of the light outputted from

the laser light source 10 non-become irregular with the signal of an NRZI code, and outputs the binary phase modulation signal (drawing 2 (c)) of 0 and pi. This phase modulation signal is inputted into the MZ interferometer 13 of the optical receiver which counters.

[0018] The MZ interferometer 13 is a configuration in which multiplex and the signal light which dichotomized input signal light to two arm waveguide with one 3dB coupler, and delay bit length D was delayed in 0< D<2 to signal light of one of these, and dichotomized with the 3dB coupler of another side is made to interfere, and changes phase modulation light into on-the-strength strange dimming according to the phase contrast. drawing 2 -- delay bit length D -- 0.8 it is -- a case -- it is -- (d) the phase contrast of two waves in which it interfered -- being shown -- (e) and (f) On-the-strength strange dimming outputted from two ports of the MZ interferometer 13 after interference is shown.

[0019] Light is received by the balance mold electric eye 14, and on-the-strength strange dimming outputted from two ports of the MZ interferometer 13 is changed into an electrical signal. This electrical signal is amplified with a linear amplifier 15, it dichotomizes further, one side is inputted into a discrimination decision circuit 18, and another side is used for clock playback. A narrow band filter 16 inputs the electrical signal which branched to clock playback, and extracts a clock frequency component. Reinforcement is uniformly controlled by the limiter amplifier 17, and the extracted clock is given to a discrimination decision circuit 18. Drawing 2 (g) The reproduced clock is shown.

[0020] In addition, delay bit length D in the MZ interferometer 13 has a desirable setup of the range of 1 / 2<=D<=1. Hereafter, the reason is explained to details. Such reception with an exact signal can be performed in the case of data reception that the pulse width of a detection signal is wide, including a clock frequency component. Here, the relation between delay bit length D, a clock frequency component, and pulse width is typically shown in drawing 3 .

[0021] The pulse width of a signal has the greatest breadth at the time of D= 1, and pulse width becomes narrow, even if larger [than D= 1] and small. If the bit currently observed is now made into the n-th bit, in D= 1, adjoining bits, i.e., the n-th bit, and the n+1st bits can interfere completely, and can detect the signal of an NRZI code efficiently. Moreover, if D becomes smaller than 1, interference of not only n+1st between the adjoining n-th and a bit but the n-th bits will occur. Consequently, pulse width becomes narrow and the signal wave form approaches the RZ code. On the limit of D= 0, pulse width is set to 0 and becomes continuation of a space.

On the other hand, if D becomes larger than 1, in addition to interference between the adjoining n-th and the n+1st bits, interference between the n-th and the n+2nd bits will occur. Since this portion only narrows pulse width regardless of the data reproduced by the receiver, although the field of 1< D<2 is ability ready for receiving theoretically, it is not practical. On the limit of D= 2, interference between the adjoining n-th and the n+1st bits is lost completely, turns into only interference between the n-th and the n+2nd bits, and becomes non-receipt.

[0022] In the above explanation, it can be said about detection of the signal of an NRZI code that it is optimal that it is D= 1. However, a clock is required for discernment of a detection signal, and it is necessary to carry out extract playback of the clock from a detection signal. For that purpose, the detection signal needs to contain the clock frequency component. Although the clock frequency component was conventionally extracted in the electric field using the EXOR circuit or the multiplying circuit by the configuration, in the configuration of this operation gestalt, by adjusting delay bit length D in the MZ interferometer 13, the signal containing many clock frequency components is generated, and clock playback is enabled with an easy configuration.

[0023] As shown in drawing 3 , near D=1/2 contains most clock frequency components, and the output signal wave of the MZ interferometer 13 turns into a wave almost equivalent to RZ signal. A clock frequency component becomes small as D goes to 0 from 1/2, and as 1 is approached, and the engine performance of a receiver falls. In addition, the predetermined clock frequency component is included also in the field of 1< D<2.

[0024] Thus, since the output signal from the MZ interferometer 13 contains [delay bit length D] many clock frequency components in the 1/2 neighborhood, the regeneration efficiency of a clock is the best. Moreover, it lifting-comes to be hard of a bit error, in case the width of face of a bit is breadth and discernment as delay bit length D approaches 1 from 1/2. On the other hand, a clock frequency component decreases and it deteriorates compared with the time of the regeneration efficiency of a clock being the delay bit length 1/2. Therefore, it can be said that delay bit length D in the MZ interferometer 13 has a desirable setup of the range of 1 / 2<=D<=1.

[0025] In addition, it is good also as a configuration to which a heater is vapor-deposited to one arm waveguide of the MZ interferometer 13, adjustable [of the optical length] is carried out using a thermooptic effect, and it carries out adjustable [of the delay bit length D].

[0026] Drawing 4 shows the example configuration which applied the optical transmitter-receiver of this invention to coherent light communication system. An optical transmitter is constituted by a laser light source 40, a phase modulator 41, and the NRZ-I encoder 42 in drawing. The optical receiver which counters an optical transmitter through an optical transmission line and an optical switching network is constituted by SAW filter 47 and the limiter amplifier 48 as the MZ interferometer 43 with which delay bit length was set as one half, the balance mold electric eye 44, a linear amplifier 45, a low pass filter (LPF) 46, and a narrow band filter, and is constituted by the D-flip-flop (D-FF) 49 as a discrimination decision circuit.

[0027] A phase modulator 41 is LiNbO3. It consists of optical waveguide formed, and drives with the signal of the NRZI code outputted from the NRZ-I encoder 42, and the phase modulation of the laser beam outputted from a laser light source 40 is carried out to an NRZI code. This phase modulation light is inputted into the MZ interferometer 43 through an optical transmission line and an optical switching network.

[0028] The MZ interferometer 43 dichotomizes input signal light, and is delayed 1/2 bit in signal light of one of these, and both signal light is made to interfere in it, and it generates on-the-strength strange dimming. In addition, on-the-strength strange dimming at this time serves as an RZ code, is outputted to two ports of the MZ interferometer 43 in a mark and a space, respectively, and is changed into an electrical signal by the balance mold electric eye 44. This electrical signal is amplified with a linear amplifier 45, and dichotomizes further, a high frequency component is cut for one side through LPF46, and pulse width can extend it, and it is inputted into D-FF49. It is inputted into SAW filter 47, a clock frequency component is extracted, reinforcement is uniformly controlled by the limiter amplifier 48, and the electrical signal of another side is given to the clock terminal of D-FF49.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The block diagram showing the operation gestalt of the optical transmitter-receiver of this invention.

[Drawing 2] Drawing showing the signal wave form of each point of drawing 1 .

[Drawing 3] Drawing showing typically the relation between delay bit length D, a clock frequency component, and pulse width.

[Drawing 4] The block diagram showing the example configuration which applied the optical transmitter-receiver of this invention to coherent light communication system.

[Drawing 5] The block diagram showing the example of a configuration of the conventional optical transmitter-receiver.

[Drawing 6] The block diagram showing the example of a configuration of the conventional optical transmitter-receiver.

[Description of Notations]

10 40 Laser light source

11 41 Phase modulator

12 42 NRZ-I encoder

13 43 Mach TSUENDA (MZ) interferometer

14 44 Balance mold electric eye

15 45 Linear amplifier

16 Narrow Band Filter

17 48 Limiter amplifier

18 Discrimination Decision Circuit

46 Low Pass Filter (LPF)

47 SAW Filter

49 D-Flip-flop (D-FF)

50 60 Laser light source

51 61 Modulator on the strength

52 62 Photodiode

53 63 Linear amplifier

54 1/2-Bit Delay Machine

55 Exclusive-OR (EXOR) Circuit

56 65 Narrow band filter

57 66 Limiter amplifier

58 67 Discrimination decision circuit

64 Multiplying Circuit

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] This invention relates to the optical transmitter-receiver which performs clock playback using a differential-phase-shift-modulation-direct detection (DPSK-DD) method in the optical transmitter-receiver used for coherent optical communication.

[0002]

[Description of the Prior Art] When an input signal is "1", the sign which reversed the last sign, and the signal of an NRZI code which turns into the last sign and an equal sign in the case of "0" are generated, and by the signal of this NRZI code, the phase modulation of the light non-become irregular is carried out, it transmits, and a DPSK-DD method is a method which detects this phase modulation light directly by the balance mold electric eye in a receiving side. Since a DPSK-DD method has good light-receiving sensitivity compared with an intensity modulation-direct detection (IM-DD) method, utilization is expected as an optical communication type suitable for long-distance optical transmission.

[0003]

Moreover, a DPSK-DD method is a differential receiving method which used the balance mold electric eye, and since it is not concerned with input signal light reinforcement but the threshold which identifies a signal can always be maintained in the center of signal amplitude, there is the feature strong against the level variation of signal light. Therefore, in recent years, utilization is expected as an optical transceiver method which applies an optical packet signal to the system exchanged in the field of light like an optical ATM switch.

[0004]

On the other hand, in optical transmission systems, such as long-distance optical transmission and an optical ATM switch, the clock playback from signal light has been an important technical

problem, and many communication modes suitable for clock playback and coding methods are proposed.

[0005]

Here, the clock playback technology at the time of using an NRZ code by the IM-DD method is explained as most general example. Drawing 5 and 6 show the example of a configuration of the conventional optical transmitter-receiver.

[0006]

An optical transmitter is constituted by a laser light source 50 and the modulator 51 on the strength in drawing 5 . The optical receiver which counters an optical transmitter is constituted by a photodiode 52, a linear amplifier 53, the 1/2-bit delay machine 54, the exclusive-OR (EXOR) circuit 55, a narrow band filter 56, the limiter amplifier 57, and the discrimination decision circuit 58.

[0007]

Intensity modulation of the light outputted from the laser light source 50 is carried out by the input signal of an NRZ code with the modulator 51 on the strength. Light is received by the photodiode 52 of the optical receiver which counters, and this signal light is changed into an electrical signal. This electrical signal is amplified with a linear amplifier 53, it dichotomizes further, one side is inputted into a discrimination decision circuit 58, and another side is used for clock playback. The electrical signal which branched to clock playback dichotomizes further, one side is inputted into the EXOR circuit 55, and another side is inputted into the EXOR circuit 55 in response to 1/2-bit delay with the 1/2-bit delay vessel 54. Consequently, a signal with the same band as a clock is outputted, and a clock frequency component is extracted from the EXOR circuit 55 by the narrow band filter 56. Reinforcement becomes fixed with the limiter amplifier 57, and the extracted clock signal is given to a discrimination decision circuit 58.

[0008]

An optical transmitter is constituted by a laser light source 60 and the modulator 61 on the strength in drawing 6 . The optical receiver which counters an optical transmitter is constituted by a photodiode 62, a linear amplifier 63, the multiplying circuit 64, a narrow band filter 65, the limiter amplifier 66, and the discrimination decision circuit 67.

[0009]

Intensity modulation of the light outputted from the laser light source 60 is carried out by the input signal of an NRZ code with the modulator 61 on the strength. Light is received by the photodiode 62 of the optical receiver which counters, and this signal light is changed into an electrical signal. This electrical signal is amplified with a linear amplifier 63, it dichotomizes further, one side is inputted into a discrimination decision circuit 67, and another side is used for clock playback. The multiplying circuit 64 inputs the electrical signal which branched to clock playback, and outputs the signal which has the same band as a clock by differential and full wave rectification, and a clock frequency component is extracted by the narrow band filter 65. Reinforcement becomes fixed with the limiter amplifier 66, and the extracted clock signal is given to a discrimination decision circuit 67.

[0010]

[Problem(s) to be Solved by the Invention] For example, 10 Gbit/s The clock frequency which is needed in a communication link in case discernment playback is performed within an optical receiver is 10GHz. However, 10 Gbit/s Since the NRZ code train is distributed over the range whose frequency band is about 0-5GHz, it does not contain a clock frequency component. Therefore, in order to extract the clock which synchronized with the signal, the electrical circuit which makes a clock frequency component is needed from the received NRZ code train.

[0011] Conventionally which is shown in <u>drawing 5</u> , in order to make a clock frequency component with a configuration, the EXOR circuit 55 is used, and with the configuration, the multiplying circuit 64 is used conventionally which is shown in <u>drawing 6</u> . Since it must drive by one twice the speed of a signal speed, these electrical circuits are dozens Gbit/s. Creation of a circuit becomes difficult in case it applies to the high-speed optical communication of a class.

[0012] This invention aims at offering the optical transmitter-receiver which can perform clock playback, without using the electrical circuit where high-speed operation is demanded taking advantage of the advantage of a DPSK-DD method.

[0013]

[Means for Solving the Problem] In an optical transmitter-receiver equipped with an optical transmitter which this invention carries out the phase modulation of the light non-become irregular by signal of an NRZI code, and outputs phase modulation light, and an optical receiver which receives phase modulation light, reproduces a clock signal, and performs a signal decision A Mach-Zehnder interferometer which an optical receiver dichotomizes phase modulation light,

set up delay bit length D to one signal light in 0< D<2, and both signal light is made to interfere, and is changed into on-the-strength strange dimming, A balance mold electric eye which receives two outputs of a Mach-Zehnder interferometer and is changed into an electrical signal, a narrow band filter which extracts a clock frequency component from an electrical signal, and limiter amplifier which makes regularity amplitude of a clock signal outputted from a narrow band filter are had and constituted.

[0014]

Moreover, as for a Mach-Zehnder interferometer, it is desirable to set up delay bit length D to one signal light in 1 / 2<=D<=1.

[0015]

[Embodiment of the Invention] Drawing 1 shows the operation gestalt of the optical transmitter-receiver of this invention. Drawing 2 shows the sign train in each point of drawing 1 .

[0016]

An optical transmitter is constituted by a laser light source 10, a phase modulator 11, and the NRZ-I encoder 12 in drawing. The optical receiver which counters an optical transmitter is constituted by the Mach TSUENDA (MZ) interferometer 13, the balance mold electric eye 14, a linear amplifier 15, a narrow band filter 16, the limiter amplifier 17, and the discrimination decision circuit 18.

[0017]

The NRZ-I encoder 12 inputs the input signal (drawing 2 (a)) of an NRZ code, and, in the case of a signal "1", in the case of the sign and signal "0" which reversed the last sign, changes and outputs it to the signal (drawing 2 (b)) of an NRZI code used as the last sign and an equal sign. A phase modulator 11 carries out the phase modulation of the light outputted from the laser light source 10 non-become irregular with the signal of an NRZI code, and outputs the binary phase modulation signal (drawing 2 (c)) of 0 and pi. This phase modulation signal is inputted into the MZ interferometer 13 of the optical receiver which counters.

[0018]

The MZ interferometer 13 is a configuration in which multiplex and the signal light which dichotomized input signal light to two arm waveguide with one 3dB coupler, and delay bit length D was delayed in 0< D<2 to signal light of one of these, and dichotomized with the 3dB coupler of another side is made to interfere, and changes phase modulation light into on-the-strength

strange dimming according to the phase contrast. drawing 2 -- delay bit length D -- 0.8 it is -- a case -- it is -- (d) the phase contrast of two waves in which it interfered -- being shown -- (e) and (f) On-the-strength strange dimming outputted from two ports of the MZ interferometer 13 after interference is shown.

[0019]

Light is received by the balance mold electric eye 14, and on-the-strength strange dimming outputted from two ports of the MZ interferometer 13 is changed into an electrical signal. This electrical signal is amplified with a linear amplifier 15, it dichotomizes further, one side is inputted into a discrimination decision circuit 18, and another side is used for clock playback. A narrow band filter 16 inputs the electrical signal which branched to clock playback, and extracts a clock frequency component. Reinforcement is uniformly controlled by the limiter amplifier 17, and the extracted clock is given to a discrimination decision circuit 18. Drawing 2 (g) The reproduced clock is shown.

[0020]

In addition, delay bit length D in the MZ interferometer 13 has a desirable setup of the range of 1 / 2<=D<=1. Hereafter, the reason is explained to details. Such reception with an exact signal can be performed in the case of data reception that the pulse width of a detection signal is wide, including a clock frequency component. Here, the relation between delay bit length D, a clock frequency component, and pulse width is typically shown in drawing 3 .

[0021]

The pulse width of a signal has the greatest breadth at the time of D= 1, and pulse width becomes narrow, even if larger [than D= 1] and small. If the bit currently observed is now made into the n-th bit, in D= 1, adjoining bits, i.e., the n-th bit, and the n+1st bits can interfere completely, and can detect the signal of an NRZI code efficiently. Moreover, if D becomes smaller than 1, interference of not only n+1st between the adjoining n-th and a bit but the n-th bits will occur. Consequently, pulse width becomes narrow and the signal wave form approaches the RZ code. On the limit of D= 0, pulse width is set to 0 and becomes continuation of a space. On the other hand, if D becomes larger than 1, in addition to interference between the adjoining n-th and the n+1st bits, interference between the n-th and the n+2nd bits will occur. Since this portion only narrows pulse width regardless of the data reproduced by the receiver, although the field of 1< D<2 is ability ready for receiving theoretically, it is not practical. On the limit of D= 2,

interference between the adjoining n-th and the n+1st bits is lost completely, turns into only interference between the n-th and the n+2nd bits, and becomes non-receipt.

[0022]

In the above explanation, it can be said about detection of the signal of an NRZI code that it is optimal that it is D= 1. However, a clock is required for discernment of a detection signal, and it is necessary to carry out extract playback of the clock from a detection signal. For that purpose, the detection signal needs to contain the clock frequency component. Although the clock frequency component was conventionally extracted in the electric field using the EXOR circuit or the multiplying circuit by the configuration, in the configuration of this operation gestalt, by adjusting delay bit length D in the MZ interferometer 13, the signal containing many clock frequency components is generated, and clock playback is enabled with an easy configuration.

[0023]

As shown in drawing 3 , near D=1/2 contains most clock frequency components, and the output signal wave of the MZ interferometer 13 turns into a wave almost equivalent to RZ signal. A clock frequency component becomes small as D goes to 0 from 1/2, and as 1 is approached, and the engine performance of a receiver falls. In addition, the predetermined clock frequency component is included also in the field of 1< D<2.

[0024]

Thus, since the output signal from the MZ interferometer 13 contains [delay bit length D] many clock frequency components in the 1/2 neighborhood, the regeneration efficiency of a clock is the best. Moreover, it lifting-comes to be hard of a bit error, in case the width of face of a bit is breadth and discernment as delay bit length D approaches 1 from 1/2. On the other hand, a clock frequency component decreases and it deteriorates compared with the time of the regeneration efficiency of a clock being the delay bit length 1/2. Therefore, it can be said that delay bit length D in the MZ interferometer 13 has a desirable setup of the range of 1 / 2<=D<=1.

[0025]

In addition, it is good also as a configuration to which a heater is vapor-deposited to one arm waveguide of the MZ interferometer 13, adjustable [of the optical length] is carried out using a thermooptic effect, and it carries out adjustable [of the delay bit length D].

[0026]

Drawing 4 shows the example configuration which applied the optical transmitter-receiver of this invention to coherent light communication system. An optical transmitter is constituted by a laser light source 40, a phase modulator 41, and the NRZ-I encoder 42 in drawing. The optical receiver which counters an optical transmitter through an optical transmission line and an optical switching network is constituted by SAW filter 47 and the limiter amplifier 48 as the MZ interferometer 43 with which delay bit length was set as one half, the balance mold electric eye 44, a linear amplifier 45, a low pass filter (LPF) 46, and a narrow band filter, and is constituted by the D-flip-flop (D-FF) 49 as a discrimination decision circuit.

[0027]

A phase modulator 41 is LiNbO3. It consists of optical waveguide formed, and drives with the signal of the NRZI code outputted from the NRZ-I encoder 42, and the phase modulation of the laser beam outputted from a laser light source 40 is carried out to an NRZI code. This phase modulation light is inputted into the MZ interferometer 43 through an optical transmission line and an optical switching network.

[0028]

The MZ interferometer 43 dichotomizes input signal light, and is delayed 1/2 bit in signal light of one of these, and both signal light is made to interfere in it, and it generates on-the-strength strange dimming. In addition, on-the-strength strange dimming at this time serves as an RZ code, is outputted to two ports of the MZ interferometer 43 in a mark and a space, respectively, and is changed into an electrical signal by the balance mold electric eye 44. This electrical signal is amplified with a linear amplifier 45, and dichotomizes further, a high frequency component is cut for one side through LPF46, and pulse width can extend it, and it is inputted into D-FF49. It is inputted into SAW filter 47, a clock frequency component is extracted, reinforcement is uniformly controlled by the limiter amplifier 48, and the electrical signal of another side is given to the clock terminal of D-FF49.

[0029]

[Effect of the Invention] As explained above, the optical transmitter-receiver of this invention can make a clock frequency component from a lightwave signal by adjusting delay bit length D of MZ interferometer. Although twice as many high-speed operation as a signal speed was needed since the clock frequency component was conventionally extracted in the electric field using the EXOR circuit or the multiplying circuit, in the optical transmitter-receiver of this

invention, the electrical circuit where high-speed operation is demanded becomes unnecessary. That is, they are dozens Gbit/s by the easy configuration. It is applicable to clock playback of the high-speed optical communication of a class.

[Translation done.]

EFFECT OF THE INVENTION

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[Translation done.]